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TYPES OF VHMS DEPOSITS OF THE URALS AND THEIR GEODYNAMIC SETTING

Рассмотрены колчеданные месторождения (КМ) Южного Урала в сравнении с мировыми типами и их геодинамическая позиция. Все типы КМ (ивановский (Ni)-Co-Cu, домбаровский (Co)-Cu, уральский Zn-Cu и Cu-Zn и баймакский Au-Ba-Pb-Cu-Zn) формировались в различных обстановках девонской островодужной системы. Локальные колчеданоносные пояса обладают поперечной и продольной зональностью. Последняя заключается в смене по простиранию пояса существенно медных руд медно-цинковыми и полиметаллическими.

The Urals is a classical province of the development of volcanogenic-hosted massive sulfide deposits. The South Urals VHMS deposits are less metamorphosed and retain the original features. The Magnitogorsk zone is most productive for sulfide mineralization in the South Urals and contains seven of eight large (100 000 t and more of ore) deposits in the Urals such as Uchaly, Novo-Uchaly, Uzelga, Sibai, Yubileinoe, Podolsk, and Gai [Prokin et al., 2011]. This gives a reason to examine in detail VHMS deposits from the Magnitogorsk zone as an example.

Based on the ore composition, the author distinguishes four main types of VHMS deposits: 1) Ivanovka (Ni)-Co-Cu, 2) Dombarovka (Co)-Cu, 3) Urals Cu-Zn and 4) Baimak Au-Ba-Pb-Cu-Zn. All types are characterized by certain correlations with ore-hosting complexes, such as basalt-ultramafic rocks, basalt, basalt-rhyolite, and basalt-andesite-rhyolite, which were formed in different geodynamic settings of the Devonian island arc system in the South Urals. The most common types were compared to the world known Noranda, Cyprus, and Kuroko types. The Zimnee deposit in the South Urals close to the other deposits of the Dombarovka ore region, however, may be referred to the Besshi type. The geological models of the VHMS deposits of the South Urals are shown in figure.

The Ivanovka type includes Ivanovka, Dergamysh, Ishkinino, South Voznesenka, and Yuldashevo deposits, which are hosted in the melange zone of the Main Ural Fault (MUF) in association with basalts and ultramafic rocks. Massive sulfide bodies occur at the top of ultramafic blocks and sheets in association with serpentinite conglobreccia. The ore clasts incorporated into serpentinite sandstones that overlap massive sulfide lenses indicate that sulfide ores were formed on a seafloor (Fig.). Later, the ores, serpentinites, and sandstones with ore clasts were probably overlain by basalts. Pyrrhotite is the major ore mineral of these deposits. The pyrite-pyrrhotite, chalcopyrite-pyrite-pyrrhotite, and cobaltite-arsenopyrite-chalcopyrite-pyrite-pyrrhotite ore types were recognized among massive ores [Melekestseva, 2007]. It is considered that the deposits were formed under conditions of the accretionary prism at the front of the Early Devonian island arc.

The Dombarovka type in the South Urals includes Letnee, Osennee, and Levoberezhnoe copper massive sulfide deposits in the same named ore district on the eastern limb of the Magnitogorsk zone. Mostly copper ore and host basalts are the specific features of these deposits. The sheetlike bodies of sulfide and magnetite ores are hosted in the Early Devonian pillow lavas and hyaloclastites of the Kiembaevo Formation (Fig). The magnetite, magnetite-chalcopyrite-pyrite, chalcopyrite-pyrite, and sphalerite-chalcopyrite-pyrite ore types were distinguished at the Letnee deposit [Ismagilov, 1978]. The magnetite ores also contain pyrite (~5%), rare chalcopyrite, sphalerite, molybdenite, hematite, and gangue minerals. This ore is localized at the basement and inside of sulfide bodies and also form individual bodies. The magnetite ores are often lenticular-banded. The host basalts at the Dombarovka type were formed in the inter-arc spreading basin, which was developed after the rift structure.

The well-known South Urals medium to large deposits (Uchaly, Sibai, Yubileinoe, Podolsk, etc.) and the giant Gai deposit belong to **the Urals type**. The Cu-Zn ores and host basalt-rhyolite and basalt-andesite-rhyolite complexes are their specific features. Based on the ore composition and geological setting, the deposits are subdivided into three subtypes: Urals I (copper massive sulfide ore with $Cu \geq Zn$ hosted in basalt of bimodal complex or at their top); Urals II (copper-zinc massive sul-

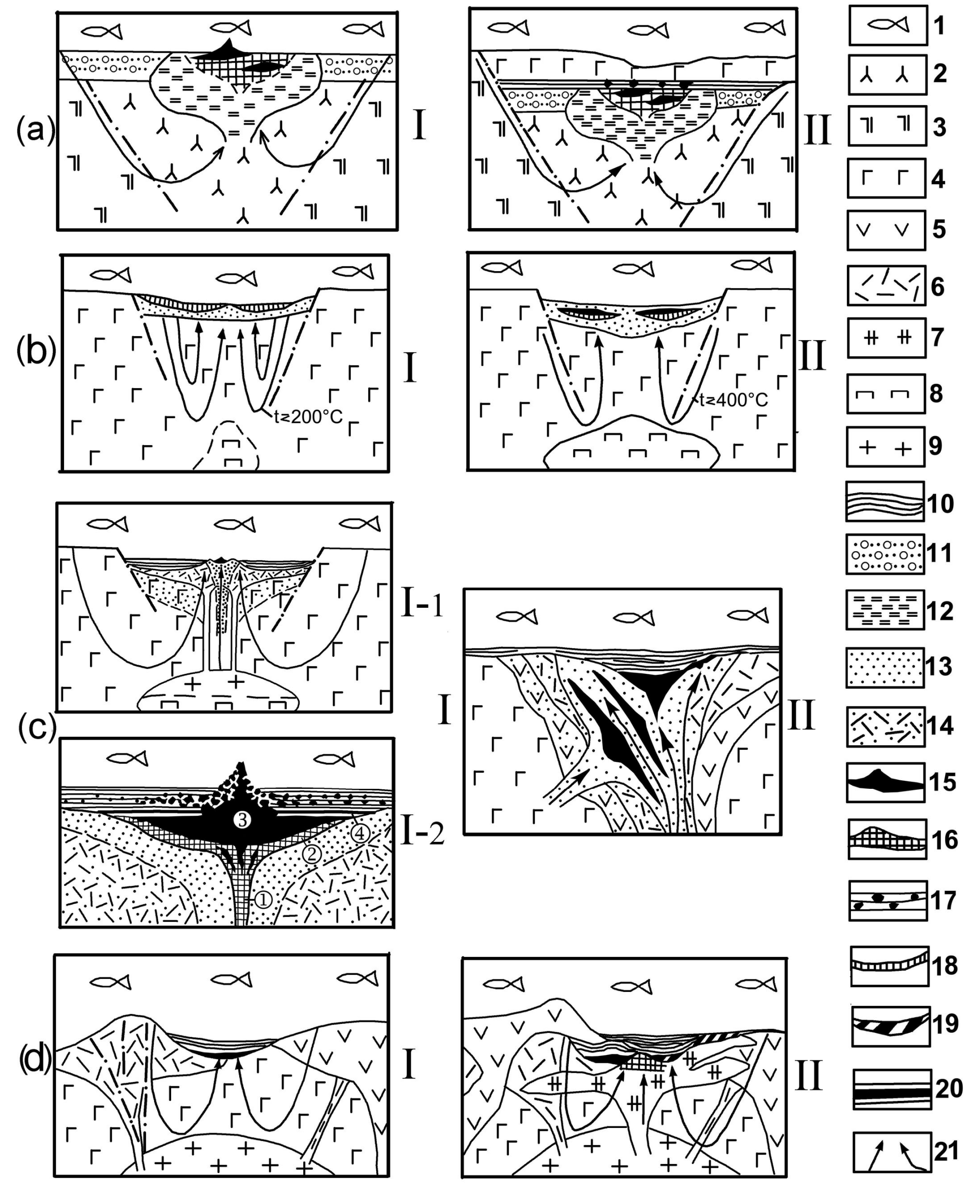

Fig. Geological models of different types of VHMS deposits in the South Urals [Seravkin, 2007]: a – Ivanovka, b – Dombarovka, c – Urals, d – Baimak types.

I – early stages of formation, II – late stages of formation; I-1, conceptual model of ore-generating volcanic edifice; I–2, model of Cu-Zn massive sulfide body of the Urals type; numerals in circles: 1, zone of feeder channels; (2–4) region of ore deposition: 2, zone of fractured volcanic rocks replaced by sulfides; 3, local depression of the sea floor filled with sulfide and terrigenous muds; 4, zone of deposition of bedded volcanosedimentary ore; (d) Baimak type: I, early Cu–Zn stage; II, late gold–barite–base-metal stage.

(1) Seawater; (2) serpentinite; (3) Ordovician–Silurian basalts; (4) Devonian basalts; (5) andesite and andesitic dacite; (6) felsic volcanics: dacite, rhyodacite, rhyolite; (7) late subvolcanic bodies of rhyodacite with quartz phenocrysts; (8, 9) magma chambers: (8) mafic and (9) felsic; (10) volcanosedimentary and sedimentary rocks; (11) serpentinite breccia, conglomerate, and sandstone; (12–14) metasomatic and partly altered rocks: (12) chlorite–talc, (13) chlorite–sericite–quartz and sericite–quartz; (14) chloritized, sericitized and propilitic rocks; (15–20) ores: (15) Cu and Cu-Zn massive, (16) impregnated, stringer–disseminated, and stockwork, (17) ore clasts in sedimentary rocks, (18) magnetite, (19) base-metal massive; (20) bedded volcanosedimentary sulfide; (21) paths of hydrothermal solutions.

fide ore with Cu ≤ Zn hosted in felsic rocks of bimodal complex or at their top); and Urals III (copper-zinc massive sulfide ore hosted in basalt-andesite-rhyolite complex).

The deposits of **the Urals I subtype** (Yubileinoe and Buribai) are hosted in the lower part of the Lower Devonian Baimak-Buribai Formation in the western part of the Buribai-Makan ore district. The deposits of the Urals I subtype are characterized by association of ore with pillow basalts. For example, at the Yubileinoe deposit, the large lenticular orebodies occur at the top of volcanic structures composed of pillow-lavas and pinch out beyond them [Seravkin, 1986]. The copper (chalcopyrite-pyrite) ore is dominant, however, pyrite and sphalerite-chalcopyrite-pyrite ores are recorded as well. The deposits of the Urals I subtype were formed in a trough on the front of an embryonic island arc (D_1e).

The Urals II subtype includes the large and well explored Sibai, Uchaly, and New Uchaly deposits, which are situated in the Sibai and Uchaly ore districts. This subtype is distinguished by the prevalence of Zn over Cu (threefold at the Uchaly deposit) and by ore localization in felsic rocks or at their tops in bimodal complexes of the Eifelian Karamalytash Formation. The ore-bearing Karamalytash Formation was formed as a result of dispersed spreading in the inter-arc basin. The ore-bearing paleovolcanoes with increased volume of felsic igneous rocks such as Sibai and Uchaly were formed in the spreading centers.

The Urals III subtype includes the medium-sized Molodezhnoe, Imeni XIX Parts'ezda, and Oktyabr'skoe deposits, the large Uzelga and Podolsk deposits, and the giant Gai deposit. These deposits are hosted in basalt-andesite-dacite complex of the Lower Devonian Baimak-Buribai Formation (Makan ore field, Gai deposit), basalt–basaltic andesite-andesite-rhyodacite complex of the Lower-Middle Devonian Irendyk Formation (Podol deposit), and basalt-basaltic andesite-rhyodacite complex of the Eifelian Karamalytash Formation (deposits of the Verkhneuralsk ore district). The deposits of the Urals III subtype are characterized by stratiform orebodies at several closely located stratigraphic levels, for example, at three levels at the giant Gai deposit. The two lower levels consist, in turn, of several orebodies. The ore layers and lenses at each level end the local rhythms of felsic volcanics. The deposits of the Urals III subtype were formed under conditions of the early island arc on a thick basaltic basement, in the large volcanic centers that underwent caldera collapse [Seravkin, 1986, 2007].

The Baimak type of gold–barite–base metal massive sulfide deposits is widespread in the Baimak, Alexandrinka, and Terensai (Dzhusa and Barsuchii Log deposits) ore districts (Fig.). In the first district, the deposits are hosted in volcanic rocks of the Baimak-Buribai Formation, partly associated with its lower basalt-rhyolite complex but largely with the overlying continuous basalt–andesite–rhyolite complex. The early copper massive sulfide and late gold-barite-base metal stages of mineralization were distinguished in the Baimak district (Fig.). The second stage of mineralization followed emplacement of rhyodacite subvolcanic bodies with large quartz phenocrysts, which ends the continuous volcanic series. Most of numerous small base metal massive sulfide, gold-barite, and gold-pyrite deposits were formed at the late stage, emphasizing the zonal ore field structure. In addition to common sulfides, the ore minerals of the Baimak type deposits include barite, tennantite, galena, bornite, native gold, and silver minerals (argentite, stromeyerite, jalpaite). The sphalerite-galena and galena ores occur in the upper part of orebodies at the Bakr-Tau, Balta-Tau and other Baimak type deposits. The deposits of the Baimak type were formed under conditions of the young island arc with sialic basement, which caused a large amount of felsic volcanic rocks of different effusive, pyroclastic, extrusive and sub-volcanic facies.

The studied types of VHMS deposits consistently correspond to the Tubinsk-Gai, Uchaly-Alexandrinka and Dzhusa-Dombarovka local volcanic belts. The metallogenic zoning of these belts (cross and lateral) is manifested by change of copper ores by the copper-zinc and further by polymetallic ores. Lateral zoning is accompanied by the dispersed mineralization and decrease in ultimate reserves of ores and trace elements.

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